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REFRACTORY MATERIALS FOR IRON AND STEEL INDUSTRIES IN NORTH KOREA

This report, by the Songim Industrial Technology Research Office, stresses the importance of refractory materials, notably silica, agalmatolite, and chamotte firebricks, in the development of the iron and steel industry in North Korea. Firebrick specifications for blast furnaces, coke ovens, open-hearth furnaces, etc., are explained.

According to the report, to reach a certain prescribed goal of iron and steel production, North Korea must produce 350 metric tons of firebrick a day for construction of various types of furnaces, and 730 metric tons daily for replacement purposes, a total of 1,080 metric tons daily.

Importance of Refractory Materials

The production of steel and iron involves the use of refractory materials capable of withstanding high temperatures. To expand her steel and iron industry, Korea must increase the production of refractory materials.

In 1936, refractory materials were used for the following purposes in the percentages indicated:

	Percent
Smelting and heat treatment of steel and iron	74
Production of ships and trains	7
Paper production and chemical industry	5
Production of cement, glass, and ceramics	4
Electric and gas industry	2
Others	8

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50X1-HUM

From the above data, it is clear how closely refractory materials are related to heavy industry. It is even possible to estimate the extent of a nation's heavy industry in terms of the quautity of refractory materials consumed in that nation. Consequently, to expand and increase the production of steel and iron, it is absolutely necessary for the nation to improve the quality and to increase the quantity of refractory materials. The life span of blast furnaces and open-hearth furnaces is dependent upon the endurance of refractory materials. If, by improving the quality of refractory materials, the life span of blast furnaces could be extended a year, or that of open-hearth furnaces a month, then the production of steel and iron would be, in turn, increased and expanded.

The refractory materials discussed here are firebricks which possess a refractory degree higher than No 26 on the SK cone /Seger?/ scale /defined below/. Firebricks should: (1) not soften easily at high temperatures, (2) change very little in volume at varying temperatures, (3) have great resistance for sudden heat changes, (4) withstand corrosion by slag and other materials, and (5) be able to stand shock, friction, etc.

For some uses, bricks which conduct heat well are needed; for other uses, bricks which conduct heat as little as possible are needed. So far, refractory materials satisfying all the above qualifications have not been found. The present practice is to choose the refractory materials according to the purpose and the requirement for each particular usage.

Refractory materials are commonly classified according to: (1) melting point, (2) material composition, (3) method of fabrication, and (4) combustibility and fusibility.

Classification According to Melting Point

Low-grade refractory materials	SK No 26-29
Ordinary refractory materials	SK No 30-33
High-grade refractory materials	SK No 34-42
Superhigh-grade refractory materials	SK No over 42

The SK cone scale consists of a table listing the melting points (arranged in upward sequence) of 59 different materials (such as feldspar, sodium silicate, limestone, etc.) which fuse at temperatures ranging from 600 to 2,000 degrees centigrade. An SK number is assigned to each of these materials. The interval between melting points varies from 20 to 30 degrees.

Comparative List of Temperatures and SK Numbers

SK No	Degrees C
022	600
021	650
020	670
019	690
018	710
017	730
016	750
0159a	790
0149a	815
0139a	835
0129a	855

50X1-HUM

SK No	Degrees C
0119a	880
0109a	900
099a	920
089a	940
079a	960
069a	980
059a	1,000
049a	1,020
039a	1,040
029a	1,060
019a	1,080
19a	1,100
29a	1,120
39a	1,140
49a	1,160
59a	1,180
69a	1,200
7	1,230
8	1,250
9	1,280
10	1,300
11	1,320
12	1,350
13	1,380
14	1,410
15	1,435
16	1,460
17	1,480
18	1,500
19	1,520
20	1,530
26	1,580
27	1,610
28	1,630
29	1,650
30	1,670
31	1,690
32	1,710
33	1,730
34	1,750
35	1,770
36	1,790
37	1,825
38	1,850
39	1,880
40	1,920
41	1,960
42	2,000

The procedure for measuring refractory degree consists of the following steps:

1. Estimate the melting point of the material to be tested. Make a triangular cone with the test material composed of granules of the same size which will melt at approximately the same temperature as the SK sample cone.

2. Place both the test cone and the SK sample cone side by side in a heating furnace. Increase the temperature at a given speed.

3. The refractory degree of the test material can then be determined by a comparison of the extent of melting of the test material with that of the corresponding SK cone.

Classification According to the Material Composition

1. Silica and clay type refractory materials that combine easily with such bases as limestone and magnesia at "acid" high temperatures.

2. Limestone, magnesia, and magnesite type refractory materials that combine easily with acids at "basic" high temperatures.

3. Chrome, alumina, chamotte, and other special types of refractory materials that are difficult to combine with the above-mentioned materials at "neutral" high temperatures.

Rate of Consumption, 1937	Percent
Chamotte and wax stone (agalmatolite) type refractory materials	65
Silica type refractory materials	32
Chrome and magnesia type refractory materials	3

Classification According to Method of Fabrication

Refractory materials may be: (1) of rectangular or irregular shape, and solid or hollow, (2) either hand-pressed or machine-pressed, (3) made by a baking or a nonbaking process, (4) of fusion mixture or nonfusion mixture.

In laying bricks, mortar is used as filler. Consequently, the mortar binder must correspond in quality and refractory degree to the brick to be bound in any particular installation.

Refractory Materials for Blast Furnaces

Before World War II, there were only one 300-metric-ton and two 350-metric-ton blast furnaces in Korea. These were located at the Hwanghae Ironworks. Construction of two 500-metric-ton furnaces was started at the Ch'ongjin Ironworks at the beginningof the war in 1941; and 48 small furnaces ranging between 15 to 30 metric tons were also constructed in Songim, Ch'ongjin, Iwon, Wonsan, P'yongyang, and in Taean Ri in Ch'olwon.

The following are brick specifications for blast furnaces:

	Hearth	Offtakes and Hot Water Tank	Shaft	Tuyeres or Breather
Refractory degree (SK)	Over No 33	Over No 32	Over No 31.5	Over No 28
Porosity (%)	Under 17	Under 22	Under 20	Under 20
Residual contraction rate after heated at 1,500° C for 1 hr (%)	Under 0.5	Under 0 5	Under 0.5	Under 0.5
Melting point of 2 kg load per sq cm (° C)	Over 1,250	Over 1,250	Over 1,250	Over 1,250
Sound	Metallic	Metallic	Metallic	Metallic

Bricks used for hearths, hot-water tanks, and offtakes must be able to withstand high temperatures, corrosion of slag, and melted pig iron. For the upper part of the shaft, bricks that contain a limited quantity of minerals or other mixtures may be used. In North Korea, Kambuk clay [from P'yongan Pukto] is used for this purpose. This clay makes as good a quality of brick as Pokchu clay [produced near Ch'olwon], which is known to be the raw material best suited for blast-furnace brick.

For hot-air furnaces, chamotte bricks that are about the same as blast-furnace bricks are used; but these bricks must be able to withstand the sudden changes of temperature which are bound to occur in this type of operation.

If the per capita demand for steel amounts to 100 metric tons, the total quantity of steel that must be produced would be 3 million metric tons [per year]. The production of 3 million metric tons of steel would in turn require 3,160,000 metric tons of steel ingot and 3,320,000 metric tons of pig iron.

To satisfy such a demand, it would be necessary to increase the present pig-iron production, which is 720,000 metric tons, by an additional 2,600,000 metric tons. This would require 15 more 500-metric-ton blast furnaces. To build 15 new blast furnaces would require 99,000 metric tons of firebricks. When it is considered that the life span of a blast furnace ranges from 5 to 7 years, after which the hot-air pipes and the tuyeres must be overhauled entirely; and that a large number of bricks are required for periodic repairs on cupola furnaces and on hot-air furnaces, then it becomes clear that the need for firebrick is very great.

Refractory Materials for Coke Ovens

Coke ovens are also made of firebrick. The usual dimensions of an oven are 10 meters high, 14 meters wide, and from 50 to 100 meters long. Approximately 70 percent of the fireproof materials used for coke ovens are silica bricks. Some agalmatolite bricks and a small quantity of chamotte bricks are also used. Silica bricks possess strong resistance to pressure during heating, and conduct heat well. Silica bricks also possess a special qualification for use in coke ovens, namely, the small residual expansion rate.

The following are the specifications of silica bricks for coke ovens:

Silicate among chemical components	Over 91%
Refractory degree	Over SK No 31
True specific gravity	Under 2.35
Porosity	Under 27%
Size of allowance	Same as standard specification

Although the number of types of refractory bricks used in coke ovens is the same as those used for blast furnaces, there is a considerable structural difference between the two types of furnaces.

Quantity of Bricks Required to Construct a Coke Oven With a Production Capacity of 10 Metric Tons per Day (MT)

	Furnace Body	Checker Chamber	Others	Total
Silica brick	98	14	0	112
Agalmatolite brick	28	2	19	49
Chamotte brick	2	0	0	2
Total	128	16	19	163

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If each of the 500-metric-ton blast furnaces consumes 103 metric tons of coke daily, 9,400 metric tons of coke must be produced daily to increase the annual production of pig iron by the desired 2,600,000 metric tons. This would also entail the construction of 11 more units of coke ovens, each unit consisting of 85 ovens /making a total of 935 ovens/.

The amount of bricks required would be as follows (in MT):

Type	One Oven Unit (85 ovens)	11 Oven Units
Silica brick	9,500	104,500
Agalmatolite brick	4,170	45,870
Chamotte brick	170	1,870
Total	13,840	152,240

Refractory Materials for Open-Hearth Furnaces

Open-hearth furnaces for steel production are of two kinds basic open-hearth and acid open-hearth furnaces. Rotating furnaces and electric furnaces are also used for steel. Basic open-hearth furnaces are more widely used than any other type. The amount of steel produced in an open-hearth furnace per heat depends on the size of the furnace a small furnace produces about 10 metric tons; a large furnace produces 100-150 metric tons, but some have an even greater capacity. In a large plant specializing in the processing of pig iron, the 150-metric-ton tilting type is used mainly. This type is approximately 27 meters long, 10 meters wide, and 13 meters high; and is made entirely of refractory materials. Like coke ovens, open-hearth furnaces are constructed mainly of silica bricks, which usually comprise 55 percent of all kinds of refractory materials used for this type of furnace. The average life span of these furnaces is very short because their operation requires temperatures in excess of 1,700 degrees centigrade. Most of the silica-type refractory materials produced are used to build steelmaking furnaces.

Percentage of Silica Type Refractory Materials Used in Steel-Producing Furnaces

	Percent
Roofs of open-hearth furnaces and of electric furnaces	85
Walls of open-hearth and electric furnaces and of checker chambers	50
Coke ovens and gas furnaces	10
Glass furnaces, refractory furnaces, and heating furnaces	5

There are several reasons why silica bricks, which are the best among the acid refractory materials, are used in basic open-hearth furnaces. One reason is that the silica refractory materials maintain comparatively strong resistance against pressure. They are used for the ceilings of open-hearth furnaces and around the gas orifices. They are also used in the checker chambers since they are excellent heat conductors. Silica bricks for the roofs of open-hearth furnaces and around gas orifices must be of the best quality. The red and white silica produced in Tamba /Kyoto and Hyogo ken/ Japan, received world-wide recognition for its superior qualities. It contains only about 2 percent iron oxide, has a small residual expansion rate, and retains viscosity at high temperatures. However, too much reliance should not be placed on Tamba as a source of supply.

50X1-HUM

Since Korea has strongly felt the need to become self-sufficient in the supply of silica bricks, research and experimentation in recent years have made it possible to manufacture them domestically by adding 3 percent furnace slag and 2 percent lime to the silica produced at Sinch'on, Hwanghae Province. Besides silica bricks, magnesia, and chrome bricks were also used for the hearths and furnace walls in open-hearth furnaces. Magnesia of excellent quality is produced in the area of Songjin and Paegam in Hamgyong Pukto and chrome iron ore with about 20 percent chrome content was discovered in the area of Ch'ongjin. There should be no difficulty in the steel-processing operation. Although the quantity of chamotte bricks required for top holes in steel-melting furnaces is small, it is very important that high-quality bricks be used; otherwise, there is a danger that melted steel may leak out, or it may reduce the temperatures of the melted steel, or it may cause the steel to stick to the brick, or otherwise produce low-grade ingots. For this reason, Korea once had to depend on importation of Japanese clay from Fukushima Prefecture. Now, however, Korea can manufacture chamotte brick domestically of equal quality through the use of the clay produced at Saenggiryong, Hamgyong Pukto, and the Kambuk clay.

Quantity of Bricks Required to Construct a 150-Metric-Ton Tilting-Type Open-Hearth Furnace (in MT)

Type	Silica Bricks	Chamotte and Agalmatolite Bricks	Magnesia and Chrome Bricks	Total
Furnace body	126	34	283	443
Orifice area	227	--	13	240
Checker chambers and slag pits	1,243	542	--	1,785
Flue and gas chimney		577	--	577
Total	1,596	1,153	296	3,045

Besides open-hearth furnaces, the production of steel requires pig iron mixers, preliminary smelting furnaces, cupola furnaces, and dolomite burning furnaces.

In Korea, facilities for steel production are much poorer than those for pig-iron production; there are only three 50-metric-ton open-hearth furnaces and one 250-metric-ton smelting furnace at the Hwanghae Ironworks. Other furnaces are the Songjin high-frequency furnace and the P'yongnam Plant of the Korean Ironworks.

Toward the end of World War II, construction of one additional 60-ton open-hearth furnace was started at the Hwanghae Ironworks, and the steel processing facilities of the Osaka Steel Plant were in the process of being moved to the Ch'ongjin Ironworks. At the termination of the war, however, the Japanese were forced to leave Korea, and the work of setting up steel production was left in the hands of the Korean people.

If our objective is set at the production of 100 metric tons of steel per capita, 3 million-metric tons of steel ingot are necessary. To meet this production quota, the following refractory materials are required for the furnace construction work.

Quantities of Brick (in MT)

	Open-Hearth Furnaces	Preliminary Smelting Furnaces	Pig-Iron Holding Furnace (mixers)	Foundry Furnaces	Magnesite Kilns	Total
Capacity (MT)	150	400	700	90	50	--
No of furnaces	30	6	6	111	36	--
Silica brick	47,880	9,660	234	--	--	57,774
Chamotte brick	4,740	966	360	819	450	7,335
Agalmatolite brick	29,850	5,964	--	825	3,000	39,639
Magnesia-chrome brick	8,880	1,950	996	--	351	12,177
Total	91,350	18,500	1,590	1,644	3,801	116,925

From 7 to 8 metric tons of chamotte brick are required for a 50-metric-ton gas furnace. The consumption of refractory material during actual operation is small as far as blast furnaces and coke ovens are concerned, but it is quite large in steel furnaces. The bottom of an open-hearth furnace must be repaired with dolomite powder after every heat of steel is produced. The roof of an open-hearth furnace can stand up for only 400 heats and sometimes for even less. The orifice area can stand only about 200 loadings, because of the concentration of high temperature in that area and the corrosive action of steel slag which forms a basic froth. Bricks for the checker chamber can be used for production up to about 800 times. Quite a large quantity of brick is consumed in ingot making since the bricks can be used only once, although there is some difference in the consumption rate depending on whether the molten steel is ladled from the top or tapped from the bottom of the furnace.

Consumption of Refractory Materials in Steel Production

Materials	Consumption per Ton Of Steel Production (in MT)	Total Quantities Required for 3 Million MT of Steel per Yr (in MT)
Silica brick	29	87,000
Chamotte and agalmatolite brick	17	51,000
Magnesia-chrome brick	10	30,000
Total	56	168,000
Magnesite powder (small grain)	38	114,000
Magnesia (small grain)	13	39,000

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Refractory Materials for Rolling Mills and Other Uses

Construction of a rolling mill that produces 3 million metri tons of rolled steel a year would require the following refractory materials:

Materials	Blooming Mill	Other Mills	Total
Silica brick	15,000	--	15,000
Chamotte and Agalmatolite brick	31,875	35,884	57,759
Magnesia and chrome brick	1,800	938	2,738
Total	48,675	20,822	75,497

A plant which produces both pig iron and steel must have a power plant. If the plant is to generate all of its own electric power by burning coal, approximately 30,000 more metric tons of chamotte bricks and agalmatolite bricks are needed. Beyond the demand already cited, foundries, cement plants, and ceramic factories also require refractory materials; however, the amount used in these industries is very small.

Conclusion

The above description gives the amount and kinds of refractory materials needed for the construction and functioning of the various productive facilities which are deemed necessary to increase adequately the future supply of iron and steel in Korea. In the paragraphs that follow, the amounts of refractory materials necessary for the construction of the additional facilities required to bring production up to the desired levels are summarized.

To build 15 blast furnaces, of 500-ton capacity each, for a total production increase of 2,600,000 metric tons of pig iron, 99,000 metric tons of chamotte and agalmatolite brick are needed. To build 11 coke oven units for the total production increase goal of 3,380,000 metric tons of coke, 104,500 metric tons of silica brick and 47,7[illegible] metric tons of chamotte and agalmatolite brick are needed. To build 30 open-hearth furnaces, of 150-ton capacity each, for the total production increase of 3 million metric tons of steel, 57,770 metric tons of silica brick, 46,970 metric tons of chamotte and agalmatolite brick, and 12,180 metric tons of magnesia and chrome brick are needed. To build an unspecified number of heating furnaces, for the total production increase of 3 million metric tons of rolled steel, 15,000 metric tons of silica brick, 57,760 metric tons of chamotte and agalmatolite brick, and 2,740 metric tons of magnesia and chrome brick are needed.

If Korea is to attain self-sufficiency on the basis of domestic production of steel at the rate of 100 metric tons per capita, she needs 443,660 metric tons of refractory materials; and, figuring a damage rate of 2 percent, the total amount required will be 530,000 metric tons. If she is to produce this amount of bricks in 5 years, she must produce at least 350 metric tons per day. To this sum must be added the 160,000 metric tons of brick expended /annually/ for steel production and the 100,000 metric tons of brick expended /annually/ for other purposes; hence, when provision is made for damage at the rate of 2 percent, the total replacement requirement becomes 220,000 metric tons. Consequently, a daily production of 730 metric tons is necessary /for replacement alone/. Adding the necessary 350 metric tons of brick for construction, she must produce 1,080 metric tons of refractory materials per day to maintain self-sufficiency in the steel and iron industry.

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Korea is self-sufficient in the necessary raw materials, and brick production requires comparatively little capital. Therefore, there is no reason why Korea cannot produce enough refractory bricks to satisfy her industrial demands for the next 10 years, as well as the next 100 years. Moreover, as metallurgy develops, more and better refractory materials may be demanded. Since it is impossible to fulfill such demands quickly, it is suggested that the expansion of the production of fireproof materials be given priority in the development of the Korean iron and steel industry.

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